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ECO BRICKS FROM WASTEWATER TREATMENT SLUDGE AND BAMBOO: A SUSTAINABLE CONSTRUCTION MATERIAL APPROACH

Danke Atharv Nagesh[1], Dhotre Rushikesh Dnyaneshwar[2], Sonawane Ashish Bhairawanath[3], S.S. Kadam[4*]

[1,2,3,4*]Department of Civil Engineering, S.K.N. Sinhgad College of Engineering, Korti, Pandharpur, Maharashtra, India.

Corresponding author: Prof. S.S. Kadam
Email: shriganesh.kadam@sknscoe.ac.in

ABSTRACT

The rapid expansion of urbanization and industrialization has led to large quantities of wastewater generation, which in turn produces significant volumes of wastewater treatment sludge. Conventional brick manufacturing heavily relies on natural soil extraction and high-energy firing processes, contributing significantly to environmental degradation and carbon emissions. This project investigates the development of sustainable, cement-free eco-bricks utilizing wastewater treatment plant sludge, soil, lime, and processed bamboo fibres. Physical and mechanical properties such as density and compressive strength across various mix proportions are evaluated to determine an optimal, eco-friendly construction alternative.

Keywords: Bamboo Fibre, Waste Water Treatment Sludge, Lime, Compressive Strength, R Square, Standard Error, Mean Square.

I. INTRODUCTION

The construction industry is one of the largest consumers of natural resources and energy. Traditional clay brick production requires topsoil excavation and high-temperature firing, causing air pollution and resource depletion. Simultaneously, wastewater treatment plants generate substantial sludge that poses severe environmental and disposal challenges if mismanaged. Bamboo is a rapidly renewable natural material with high strength and a fibrous structure that can be utilized to reinforce composite materials. By integrating wastewater treatment sludge and bamboo fibres into eco-brick production, this project provides a sustainable waste-to-resource solution that eliminates the need for conventional cement and reduces reliance on natural soil.

II. MATERIALS

The raw materials utilized in the fabrication of the eco-bricks include:

- **Soil:** Acts as the primary base material providing basic shape, structural body, and overall stability to the brick matrix.
- **Wastewater Treatment Plant Sludge:** Serves as the primary waste-derived additive, converting industrial/municipal byproducts into a useful construction material.

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- **Lime:** Functions as a stabilizing and binding agent replacing cement, enhancing particle bonding, strength, and durability while reducing soil shrinkage.
- **Bamboo Fibre:** Acts as natural, lightweight micro-reinforcement that helps control drying cracks and improves toughness and internal bonding.
- **Water:** Added gradually to render the mixture workable for proper moulding and compaction.
- **Mould:** Standardized steel or rigid moulds used to shape and compact the mixture into uniform brick specimens.

III. METHODOLOGY

The experimental methodology follows a systematic sequence from raw material collection to final testing:

1. **Collection and Pre-treatment:** Wastewater sludge and bamboo waste are collected, dewatered, dried, cleaned, ground, and sieved to achieve uniform particle sizes. Soil is similarly cleaned, dried, and sieved to remove unwanted stones and roots.
2. **Mix Proportioning:** Different weight proportions of soil, wastewater sludge, lime, and bamboo fibre are measured precisely.
3. **Mixing and Moulding:** The dry ingredients are thoroughly blended, water is added to achieve optimal workability, and the mixture is placed into moulds.
4. **Compaction:** The mixture is mechanically compacted inside moulds to minimize internal voids and ensure structural uniformity.
5. **Curing and Drying:** Moulded eco-bricks undergo controlled curing and drying to develop adequate mechanical strength.
6. **Testing:** The finished eco-bricks are subjected to physical and mechanical testing, including density and compressive strength evaluations.

IV. RESULTS

4.1 Mix Proportions

Table 4.1 and Table 4.2 summarize the percentage and absolute mass proportions used across different trial mixes.

Table 4.1: Quantity For Bricks in Percentage

Proportion	Soil (%)	Wastewater Sludge (%)	Lime (%)	Bamboo Fibre (%)
1 (A)	50%	25%	20%	5%
2 (B)	45%	30%	20%	5%
3 (C)	40%	35%	20%	5%
4 (D)	35%	20%	40%	5%
5 (E)	30%	20%	45%	5%

Table 4.2: Quantity For Bricks in Kg

Proportion	Soil (kg)	Sludge (kg)	Lime (kg)	Bamboo (kg)
1 (A)	1.125 kg	0.625 kg	0.50 kg	0.125 kg
2 (B)	1.125 kg	0.75 kg	0.50 kg	0.125 kg
3 (C)	1.000 kg	0.875 kg	0.50 kg	0.125 kg

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4 (D)	0.875 kg	1.000 kg	0.50 kg	0.125 kg
5 (E)	0.750 kg	1.125 kg	0.50 kg	0.125 kg

4.2 Density Results

Table 4.3: Density Table

Proportion	Mass (kg)	Volume (m^3)	Density (kg/m^3)
Proportion A	2.180	0.001539	1416.50
Proportion B	2.360	0.001539	1533.46
Proportion C	2.370	0.001539	1539.96
Proportion D	2.410	0.001539	1565.95
Proportion E	2.980	0.001539	1936.32

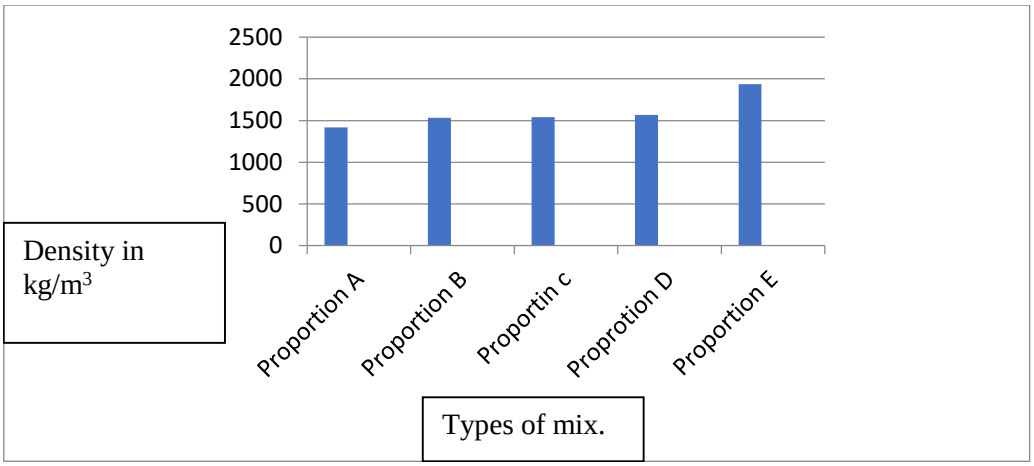


Figure 1: Density of brick

Density of brick was obtained as shown in figure 1. Maximum density obtained for mix proportion E.

4.3 Compressive strength of brick

Table 4.4: Compressive strength of brick

Sr. No	Proportion	Load (N)	Area (mm^2)	Compressive Strength (N/mm^2)
1)	A	$45x10^3$	17100	2.63
2)	B	$40x10^3$	17100	2.33
3)	C	$40x10^3$	17100	2.33
4)	D	$30x10^3$	17100	1.75
5)	E	$30x10^3$	17100	1.75

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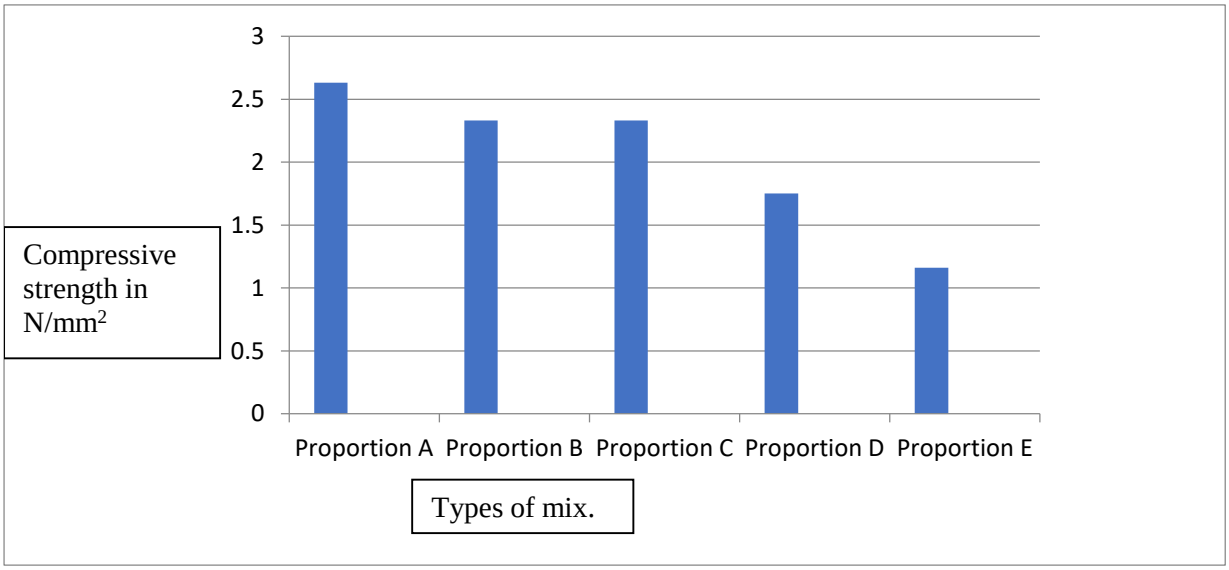


Figure 2: Compressive strength of brick

Compressive strength was obtained as shown in figure 1. Maximum compressive strength obtained for mix proportion A.

V. DISCUSSION

The experimental findings demonstrate the technical feasibility of incorporating wastewater treatment plant sludge and bamboo fibres into eco-brick manufacturing without using traditional Portland cement. The results of compressive strength of bricks.

In this model, Compressive Strength (Y, in N/mm^2) is evaluated as a function of two primary independent variables: Wastewater Treatment Sludge Percentage (X_1) and Lime Percentage (X_2).

5.1 Regression Analysis for Compressive Strength

To understand the combined influence of wastewater treatment sludge and lime stabilization on the mechanical performance of the eco-bricks, a multiple linear regression model was developed using the experimental dataset from Table 4.1 and Table 4.4.

5.1.1 Regression Statistics

The summary output of the regression model indicates a strong correlation between the mix proportions and the resulting compressive strength.

Table 4.5: Regression statics

Statistical Parameter	Multiple R	R Square (R^2)	Adjusted R^2	Standard Error	Observations (n)
Value	0.9542	0.9105	0.8210	0.2248	5

- R^2 Value (0.9105): Approximately 91.05% of the variability in the compressive strength of the eco-bricks is explained by the proportions of wastewater sludge and lime in the

Table 4.5: Significance F

Source	Degrees of Freedom (df)	Sum of Squares (SS)	Mean Square (MS)	F-Statistic	Significance F
Regression	2	1.382	0.691	13.68	0.068
Residual	2	0.1011	0.0505	—	—
Total	4	1.4831	—	—	—

Empirical Regression Equation: Compressive Strength $= 4.520 - 0.030(\text{Sludge }\%) - 0.055(\text{Lime }\%)$

VI. CONCLUSION

This study successfully developed and evaluated cement-free eco-bricks utilizing wastewater treatment sludge, soil, lime, and bamboo fibres.

Key conclusions include:

1. Wastewater treatment sludge can be effectively repurposed into construction masonry units, significantly reducing landfill disposal burdens and conserving natural topsoil.
2. The inclusion of lime and bamboo fibres provides adequate stabilization and crack control.
3. Optimal mix proportioning (such as Proportion A) achieves satisfactory physical and mechanical performance suitable for non-load-bearing walls, partitions, and sustainable construction applications.

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